TECHNICAL REPORT
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INVESTIGATION OF THE PERFORMANCE OF AN OPEN-FLAME CONVECTOR

by

Alexander Levin

June 1966

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

U.S. ARMY MATERIEL COMMAND

Mechanical Engineering Division

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ABSTRACT

This report discusses the results of the first phase of an investigation to evaluate the performance of an open-flame convector which was initiated at the request of the Army Research Office, Department of the Army, and conducted at the Mechanical Engineering and Climatic Research Laboratories, U. S. Army Natick Laboratories. The convector investigated was an experimental prototype designed as a body warmer to heat the space between the wearer's body and his outer apparel.

Three prototypes were investigated under a series of conditions including standard, low-temperature, and operational. Under these conditions, data on ignition, fuel regulation, fuel consumption, convector thermal capacitance, and safety were obtained.

Results of the investigation showed that operation of the prototype convectors can be regulated for consistent operation within 9 percent. If the fuel rate is monitored and controlled, the convector thermal capacitance may be regulated within 5 percent to assure the constancy of this variable when applied to human test subjects.

Although there is a potential hazard of fire, heat injury and toxicity from use of the open-flame convector as a body warmer, its performance within safety threshold limits is obtainable. The fire and heat injury hazards are minimized when the fuel regulating valve is prewarmed at low temperatures and the burner is ignited in a shielded enclosure.

Carbon monoxide concentration was reduced to acceptable threshold limits, less than 0.01 percent, when the convectors were operated at low-temperature operational conditions.

INVESTIGATION OF THE PERFORMANCE OF AN OPEN-FLAME CONVECTOR

I. Introduction

A. Military Interest

Improvement of the soldier's capability and performance at low-temperature enviromental conditions is a continuing objective in the U. S. Army's research and development programs to prevent cold injury.

Present combat clothing, if worn properly, furnishes good protection against cold injury hazards. When operational situations permit, this protection is upgraded by man-portable shelters and the use of field-type space heaters. Frequently, operational situations do not allow use of heated shelters. Under these conditions, insulation or heat must be added to the combat clothing ensemble to maintain body warmth at a physiologically acceptable level.

B. Technological Considerations

Since the resistance to conductive heat transfer by insulation varies directly as its thickness, protection that is obtained by adding insulation results in cumbersome clothing bulk. This type of clothing also restricts freedom of motion. On the other hand, if the space encapsulated by the existing clothing layers is warmed*, the temperature gradient at the body surface is reduced and the environment surrounding the skin is raised to a "comfortable" temperature without affecting the wearer's freedom of body motion.

The addition of heat to clothing has been tried in many ways. Technology available for accomplishing this result without heat injury hazard to the wearer is quite extensive[1]. Three principal techniques are involved: stored heat, in-situ reactions, and kinetic systems.

Stored-heat techniques are identified by devices, such as hot water bottles, heated stones or mixed fresh embers and sand wrapped in aluminum foil. Exothermic and catalytic combustion mechanisms illustrate in-situ reaction technology. In these devices, heat is generated as a by-product from a chemical reaction. Distribution of the heat is a function of the area over which the chemical reaction is taking place. In kinetic systems, heat and power are generated in a miniaturized pack that is worn or carried outside the clothing. Heat is circulated by the medium of a pumped or otherwise energized fluid: liquid, gas or electron. A network of small tubes, ducts, or fine wires in the clothing ensemble distribute the circulating fluid.

C. Background of Current Investigation

A more recent scheme suggested for investigation and evaluation

*Evacuated spaces can also accomplish same general effect.

is shown by the prototype heating device in Figure 1. The principle of design is based on a natural draft heat-exchanger device of the convector type. In this arrangement, the free-convection flow of air in a vertical tube is accelerated to forced-convection by the injection of a high-velocity stream of flame. A simplified version illustrating the principle of operation and application is shown in Figure 2.

A previous investigator of this scheme claimed that the experimental prototype, when worn as a body warmer, permits the wearer to remain in the cold under static conditions for long periods of time without discomfort. Prevention of frostbite and reduction in clothing are also claimed.

Since substantial scientific data were not furnished to prove or disprove these claims, the U. S. Army Research Office requested a detailed investigation of the device by the U. S. Army Natick Laboratories.

D. Scope and Purpose

Based on analysis of the previous investigator's claims, the scope of the Natick Laboratories investigation was divided into two phases. The first phase was limited to investigation of the device as an open-flame-type convector. The second phase examined the effectiveness of the convector in extending the exposure time of human test subjects at a constant low-temperature condition.

The purpose of this report is to present the results of the first phase and to discuss the factors relevant to use of the device with human test subjects.

II. Plan of Investigation

A. Identification of Prototypes

Three sample open-flame, convector-type heating devices, identical to the prototype shown in Figure 1, were used in this investigation. The prototype is described in Appendix I.

Each sample was marked by a number, "1", "2", or "3", inscribed only on the combustor-regulator assembly. This method of marking was used to distinguish between each prototype sample because a pretest inspection disclosed some differences in the fabrication of the assembly components.

B. Instrumentation and Apparatus

1. Temperature Instrumentation

Temperatures were measured by 20-gauge, iron-constantan

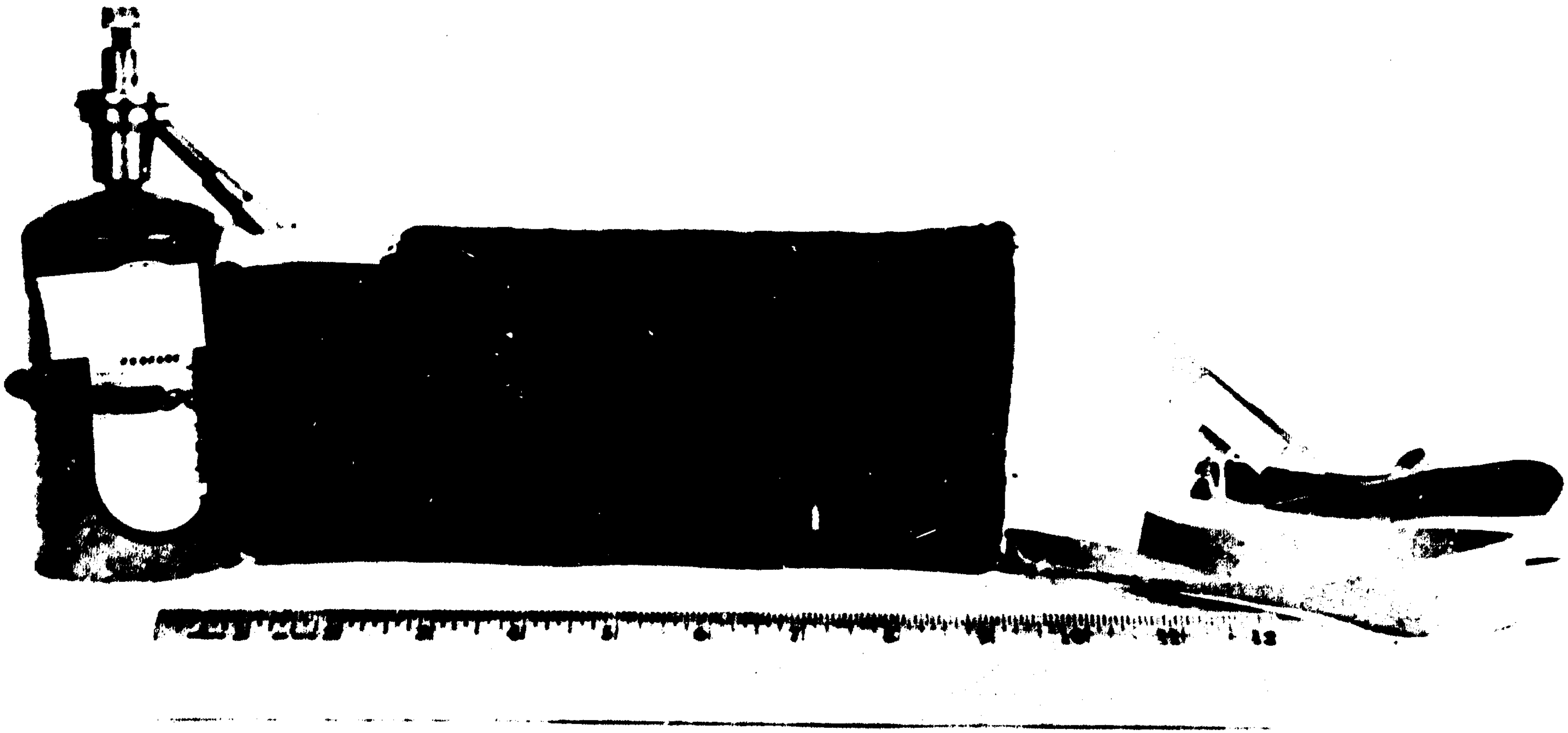

Figure 1. Prototype Convector

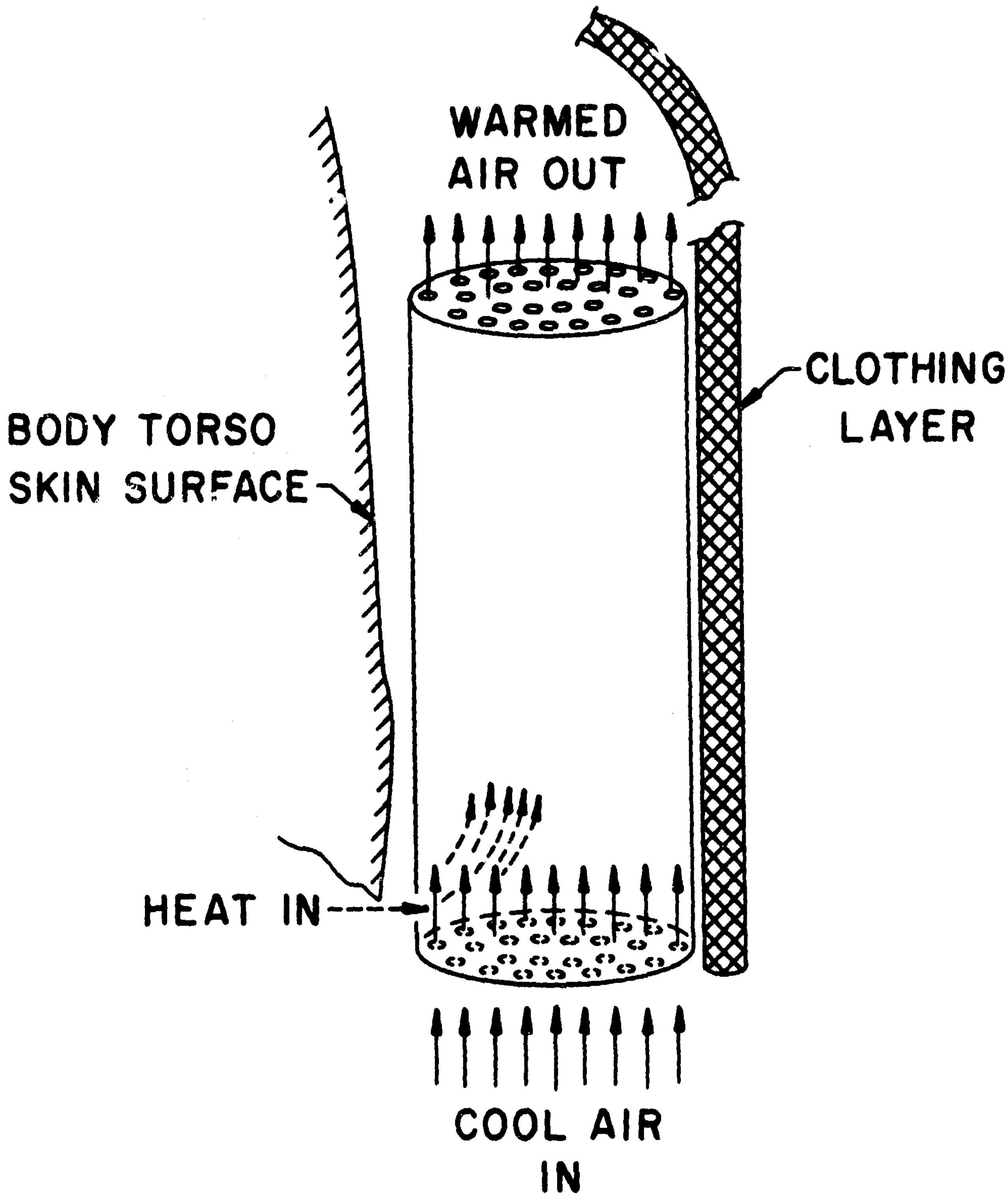

Figure 2. Principle of Open-Flame Type Convector

thermocouples, directly connected to a fully compensated, 0-800°F range, 8-point continuous recorder.

2. Weighing Instrumentation

Measurements of weight were obtained by use of a weighbeam-type scale with a direct- and reverse-reading indicator, 0-5-pound range with accuracy of ± 0.005 pound.

3. Carbon Monoxide Apparatus

Air samples were obtained by a rubber, squeeze-type bulb aspirator. Glass vials containing gauze impregnated with potassium pallado-sulphite were used to detect carbon monoxide concentrations in each air sample. The carbon monoxide level of concentration was measured by a colorametric comparator. For continuous detection of dangerous levels of carbon monoxide concentration at standard conditions, a carbon monoxide alarm was used at a predetermined setting of 0.02 percent. At low-temperature conditions, an infrared analyzer, with full-scale range of 0 to 0.2 percent, measured and recorded carbon monoxide concentrations continuously.

4. Special Test Apparatus

A special fixture was designed and fabricated to support each test prototype in a vertical position to accommodate continuous operation and measurements.

To calibrate fuel measurements and control fuel flow rates during tests, a jig and throttling index were designed, fabricated and installed on each regulating valve.

C. Methods and Procedures

1. General

Thirty propane cylinders were each marked by an identifying serial number and weighed in the "as received" condition. Unused propane cylinders were chosen randomly for each test run. These were also weighed immediately before and after each test.

After ignition of the three combustor-regulators, the burner was adjusted by a predetermined setting of the fuel throttling index jig. Each convector was assembled and installed in the operating test fixture on its assigned weighing scale. The weighing scale was read at regularly timed intervals to record fuel consumption and to determine fuel rate.

Thermocouples were located at the top and bottom caps of the convector exchanger duct and positioned to measure the inlet and outlet temperatures without affecting the weighing scale measurements.

Detailed instructions on all methods and procedures used are recorded[6,7].

2. Calibration Procedures

Calibration of the fuel regulating valve was not furnished. Therefore, a fuel throttling index was included with the specially designed jig. It provided reference points for manual control of the fuel regulating valve.

The lowest possible fuel burning rate was determined by observing the instability points of the burner flame. The upper limit was set at the mechanical stop of the manually controlled valve stem thumbscrew.

Three arbitrary points on each fuel throttling index jig were selected to approximate low-, medium- and high-fire fuel rates. Tests were conducted at each setting until the fuel cylinders were expended. Tests were repeated for at least three conditions.

3. Performance Measurements

The performance of the three prototype open-flame-type convectors was investigated under three principal conditions of test: Condition I - standard (temperature 70°F, wind velocity - 0 mph); Condition II - low-temperature (temperature 0°F, wind velocity - 0 mph); Condition III - operational (temperature 0°F, wind velocity - 2.5 to 5 mph).

Under the three principal conditions of the test, burner ignition, fuel regulation, fuel consumption, convector thermal capacitance, toxicity and safety hazards were investigated.

4. Experimental Design

The experimental design, shown in Appendix II, was developed to provide a sequence of conditions that would assure maximum thermal stressing of all the prototypes. All the sample prototypes were also tested simultaneously under identical conditions to determine a common operational point.

Condition III tests were designed to determine whether constant and identical performance could be obtained for equivalent settings of each of the three valves.

III. Results and Discussion

A. Performance at Standard Conditions

1. Ignition

All burners were easily ignited by a match after the fuel was turned on at a low rate. If a lighted match was held at the burner prior to turning the fuel on slowly, no ignition difficulty was experienced. If the fuel was turned on rapidly, the lighted match was extinguished without sustaining burner ignition.

2. Fuel Regulation

The fuel rate, in pounds per hour, was calculated directly from measurements of the average weight of fuel consumed over a fixed period of time. Average fuel rates were obtained over four- and eight-hour durations, as well as over the time span required to expend a full cylinder of fuel. For any one setting of the fuel throttling index, it was found that the fuel rate was not regulated better than 9 percent over the rate established for a four-hour period. Since regulation of the fuel rate did not remain constant but decreased with time, the regulating valve did not perform as a standard automatic pressure regulator. It functioned primarily as a proportionally sensitive, manually-controlled orifice to vary the flow of fuel through the full range of zero to maximum. To this extent, the valve may be properly called a fuel-flow regulator. Acceptable regulation of the fuel rate for any fixed setting of the valve was obtained within a four-hour period provided a full cylinder of propane fuel was used.

Figure 3 shows the results of plotting the average fuel rates in pounds per hour as a function of the fuel throttling index or valve position. The curves for prototypes 2 and 3 indicate similar characteristics of fuel regulation since they have proximately equal slopes. The curve for prototype 1 is also a straight line, but its regulation characteristic or slope is quite different.

3. Toxicity

Over a period of 43 hours, 28 measurements were made of carbon monoxide concentration at the top cap of each of the prototype convectors. Prototype convector 2 showed the highest percentage of carbon monoxide concentration. At the low fuel rate, and over a period of 9 hours, the carbon monoxide concentration was repeatedly measured at 0.05 percent. Prototype convector 3 showed imperceptible concentrations of carbon monoxide at all fuel rates. Carbon monoxide measurements at all fuel rates of prototype convector 1 showed no concentration exceeding 0.02 percent.

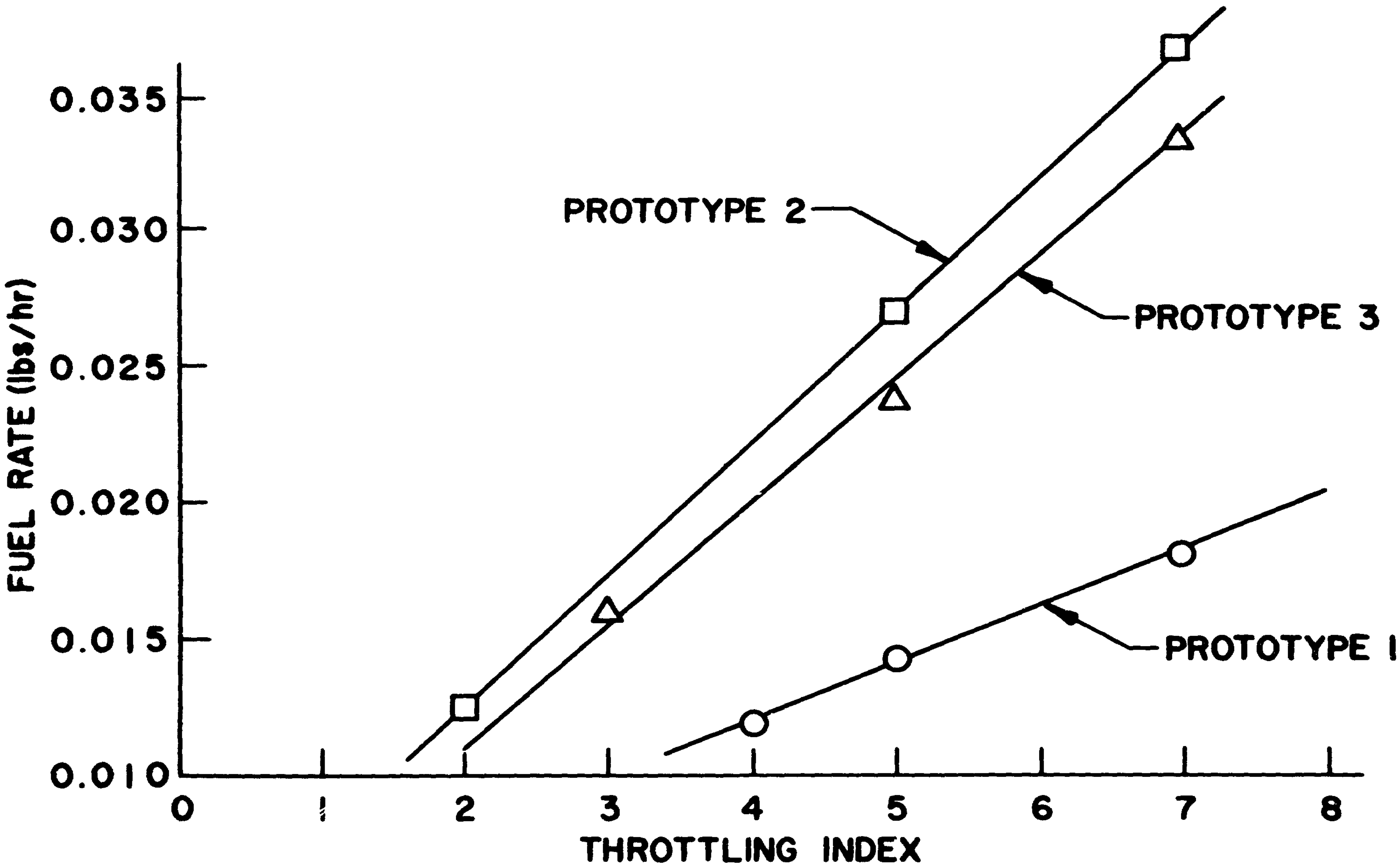

Figure 3. Fuel Regulation - Standard Conditions

4. Safety Hazards

Based on review of data[8], it was found that the toxicity measurements indicate a degree of risk if these prototypes are used in the breathing zone of the average adult in good health. At a 0.05 percent carbon monoxide concentration, "perceptible effects" are noticeable in one-half hour. Headache and nausea usually occur within 1-1/4 hours. At a 0.02 percent carbon monoxide concentration, perceptible effects result in 1-1/2 hours; 3-1/4 hours are required to produce headache and nausea.

B. Performance at Low-temperature Conditions

Following tests conducted at standard conditions, all prototype convectors, including fuel cylinders, were cold-soaked at $0^{o}F$ for 72 hours before ignition and fuel regulation tests were initiated. These tests were also conducted at $0^{o}F$.

1. Ignition

The cold-soaking test disclosed a number of problems relevant to ignition and shutoff of the burner within a short period after ignition.

It was found that ignition response was much slower and that it varied between each of the units. After ignition was terminated, by shutting off the valve, the burner continued to burn with a lazy flame. When rechecked, the combustor-regulators of prototype convectors 1 and 2 indicated that liquid propane was leaking from the valves.

Inspection of the valve interiors disclosed that the rubber diaphragm tended to set at the low-temperature condition and hold a ball check valve open to fuel flow. Leakage resulted from a poorly designed valve seal that required a gasket when the material was cold-stressed.

Warming of all valves prior to their assembly to the fuel cylinders eliminated the ignition difficulties.

2. Fuel Regulation

Fuel regulation results obtained at low-temperature conditions are plotted in Figure 4.

The relationship between the curves of prototypes 2 and 3 is similar to that in Figure 3 for standard conditions, except at low throttling index values. The results plotted for prototype 1 are also shown. The slope of this curve is identical to that in Figure 3 for standard conditions; however, its displacement is the reverse of the results plotted for prototypes 2 and 3.

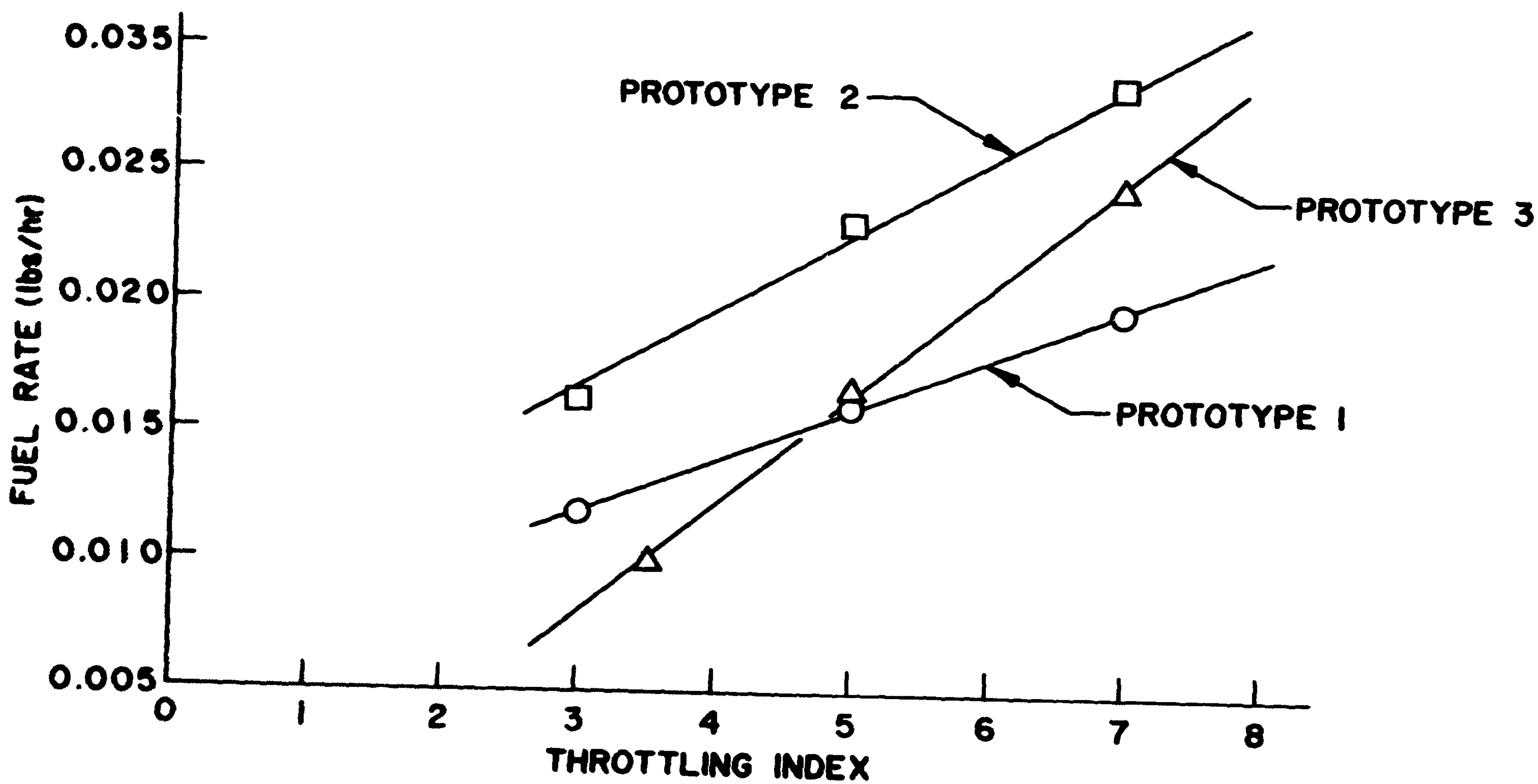

Figure 4. Fuel Regulation - Low Temperature Conditions

A material and component design investigation confirmed the inconsistency of prototype 1. A unique structural difference in the components of prototype 1 caused a larger flow of fuel at low-temperature conditions.

After the interior of the valves was cleaned following the material and component investigation, fuel regulation was rechecked. The results, plotted in Figures 5, 6, and 7 illustrate the effects of maintenance servicing on the fuel regulation performance.

3. Toxicity

Carbon monoxide concentration was measured as before. Prototype convector 2 again showed the highest percentages of carbon monoxide concentration which was 0.04 to 0.07 percent over a six-hour period.

Prototype convector 1 reached a maximum concentration of 0.02 percent. The carbon monoxide concentration measured at prototype convector 3 proved to be insignificant.

4. Safety Hazard

The results of ignition tests conducted under low-temperature conditions, and measurements of carbon monoxide concentration after tests under the same conditions, disclosed two serious risks: the potential of a fire from all units, and the toxic effects from the exhaust products of prototype convector 2.

Prewarming all the valves prior to use or avoiding cold-soaking eliminated fuel leaks and reduced the potential fire hazard.

Since the high carbon monoxide concentration indicated a lean combustion mixture, the secondary air ports of all burner tubes were inspected and cleaned. A recheck test demonstrated that the carbon monoxide concentration was reduced to an acceptable threshold level of 0.01 percent[8].

C. Performance at Low-temperature Operational Conditions

To determine performance of the open-flame-type convectors at a minimum level of operational conditions, a series of tests was conducted in the Climatic Research Laboratory of the U. S. Army Natick Laboratories as shown in Figure 8. Maximum wind velocity was held between 2 and 3 mph, and temperatures did not exceed $0^{\circ}F$ or fall below minus $2^{\circ}F$.

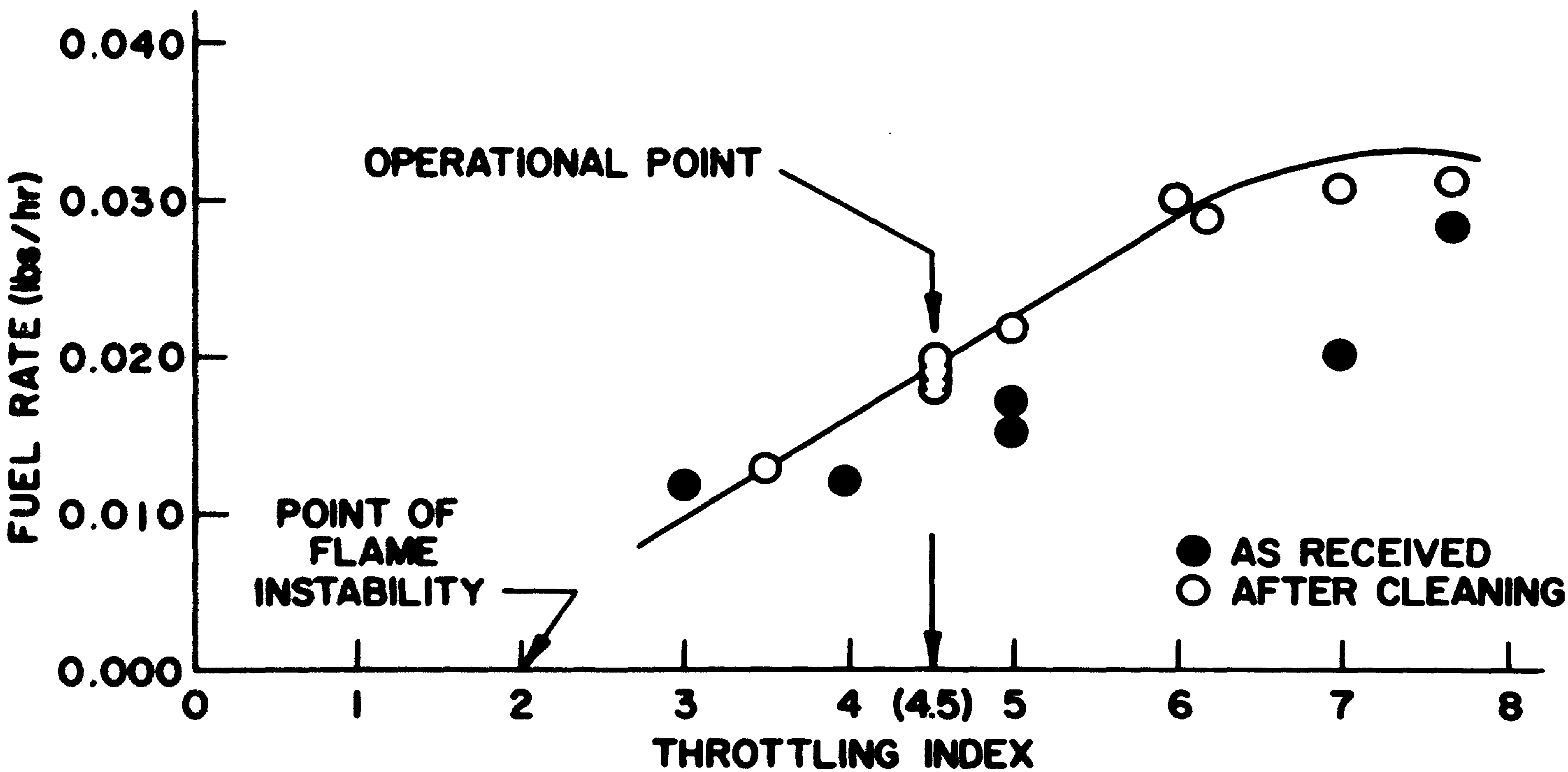

Figure 5. Fuel Regulation Performance for Prototype No. 1 and Low Temperature Operational Condition

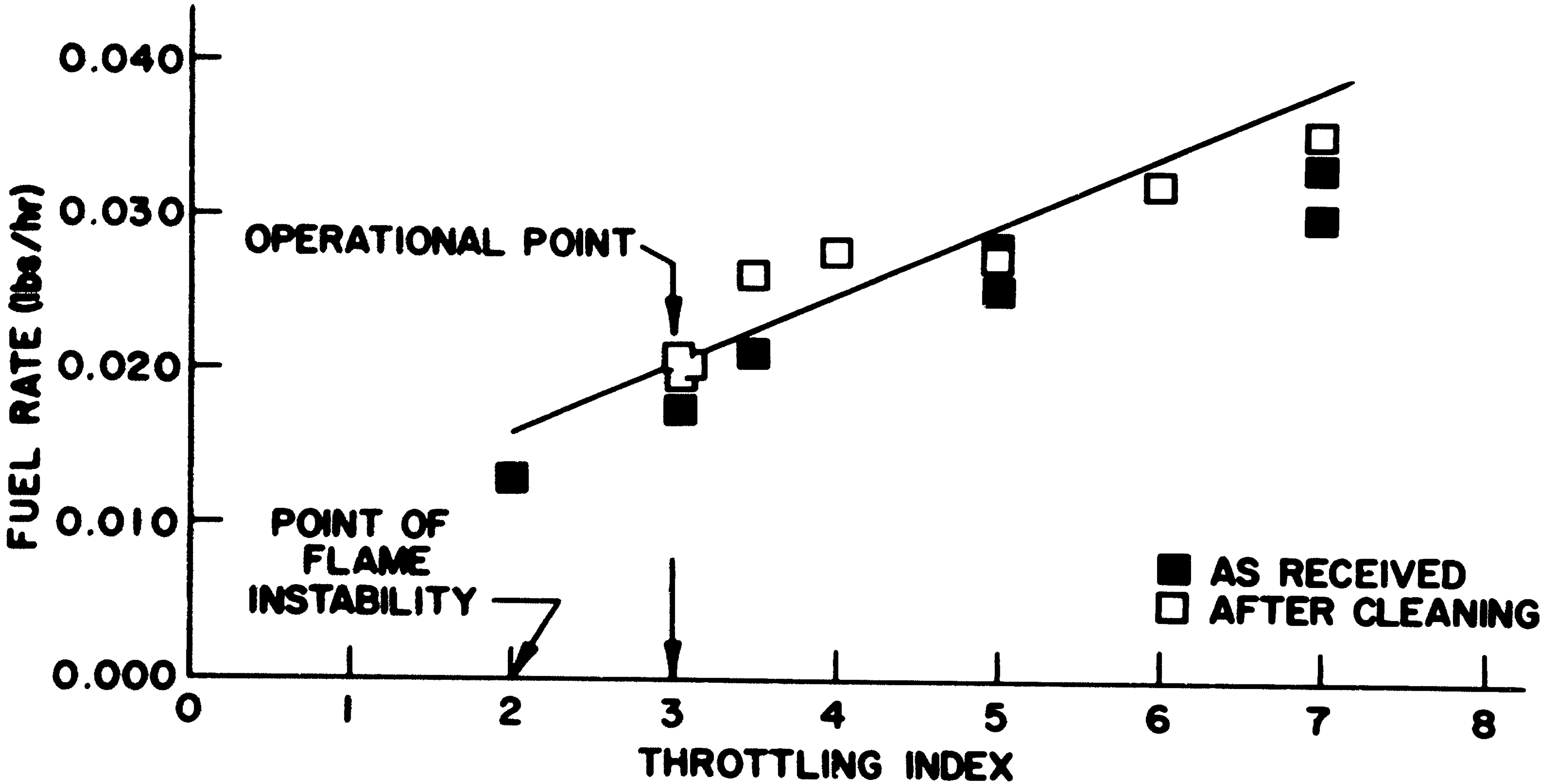

Figure 6. Fuel Regulation Performance for Prototype No. 2 and Low Temperature Operational Condition

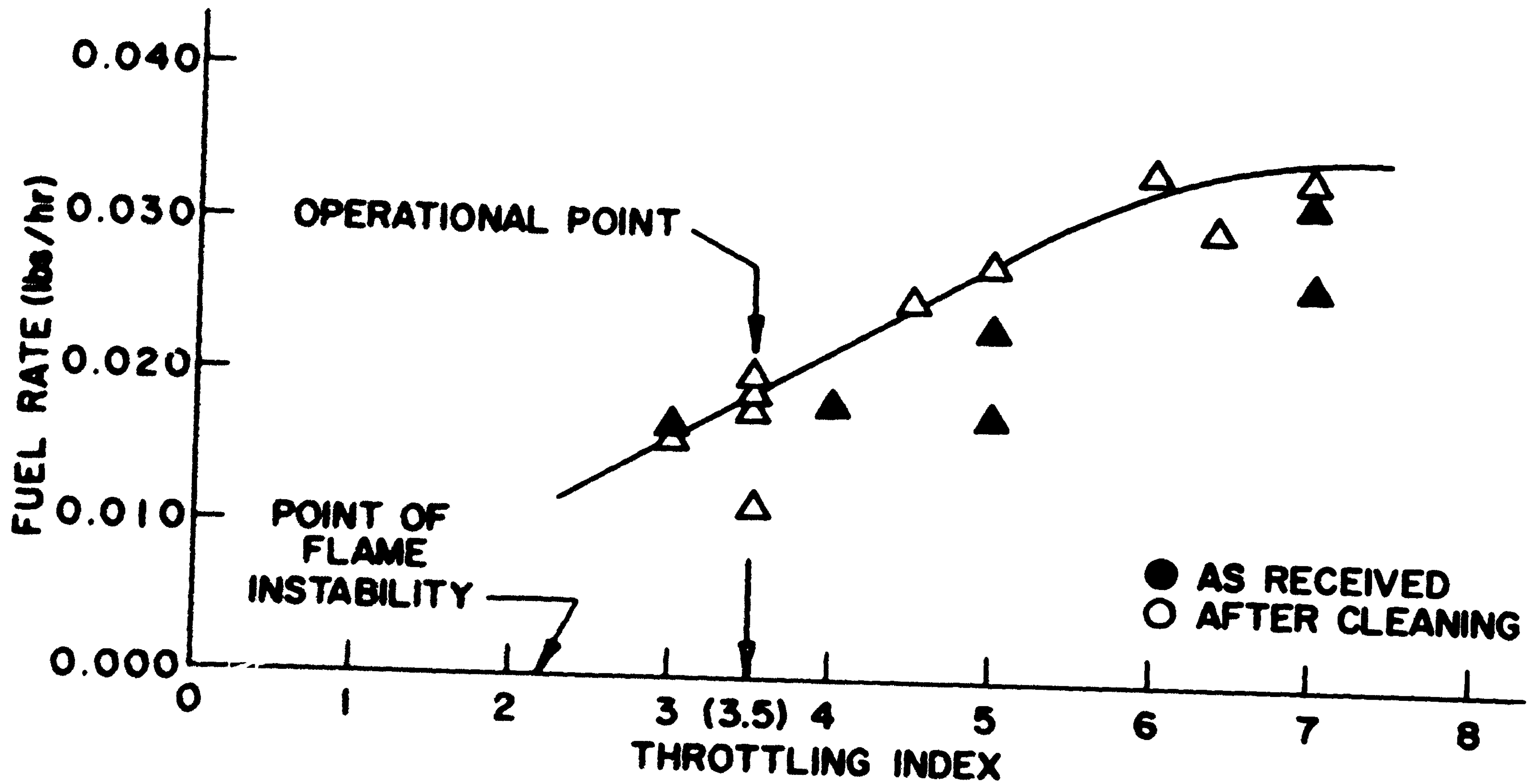

Figure 7. Fuel Regulation Performance for Prototype No. 3
and Low Temperature Operational Condition

Figure 8. Low-Temperature Operational Facility

1. Ignition

It was not possible to ignite the fuel when the burner tubes were directed into the wind. No difficulty was encountered when the burner tubes were shielded or were directed away from the wind.

2. Fuel Regulation

From interpretation of data reported by Belding and Gmitter[2], a heat rate of 400 Btuh was selected as an operational level for the convector.

Based on the heating value of propane[5], the fuel rate equivalent of 400 Btuh is 2 x 10^{-2} pounds per hour. For this rate, the throttling indexes of all prototype convectors were derived from the curves in Figures 5, 6, and 7.

Fuel regulation at each of the operational points of the throttling index is also shown in the above Figures. The results demonstrate very clearly that the fuel rate for all three valves can be regulated within 5 percent.

3. Fuel Consumption

Fuel consumption is a function of the capacity of the fuel cylinders, point of flame instability at low fuel rates, and mechanical limits of the valve.

Data collected from eleven sample fuel cylinders showed a mean total fuel capacity of 0.404 pound, with maximum deviation of minus 0.014 pound.

Figure 9 shows the fuel consumption limit curves derived for all three prototype convector valves, based on plotting burning rate as a function of fuel rate in pounds per hour and equivalent heat rate. The curve illustrates the wide burning span for each valve. It is shown that all three valves can be operated together without interruption up to 20 hours for the operational test point selected.

4. Convector Capacitance[3,4]

From a sample analysis of the recorder data charts of the inlet and outlet temperatures and measurements of the corresponding fuel rates, the thermal capacitance was calculated. Table I summarizes the mean values for each convector.

Since the prototype convector is, in principle, almost a natural draft heat pump, the mass of heater air transferred by it is a measure of its effectiveness. The number shown in column 5 of the

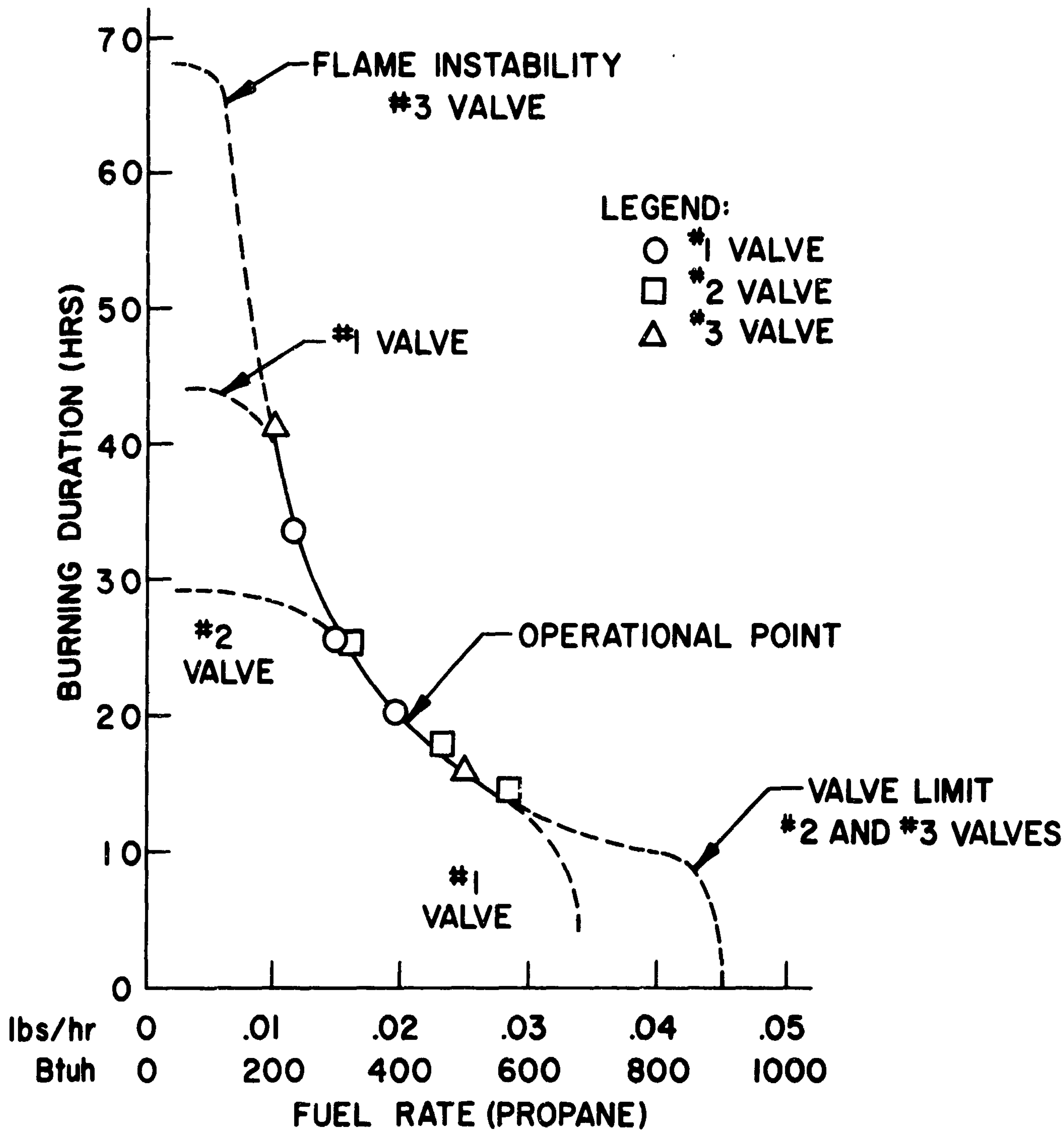

Figure 9. Fuel Consumption Limits

Table is actually the product of the mass of air transferred and its specific heat, and is a measure of the thermal capacitance of the convector (Appendix III).

Table I

Performance Data - Convector Thermal Capacitance

Convector No.	Heat Rate Btuh	Inlet Temp. ^oF	Outlet Temp. ^oF	Temp Diff. ^oF	Convector Capacitance Btuh/^oF
1	366	58	224	166	2.20
2	380	70	231	161	2.36
3	356	71	242	171	2.08

The values in column 5 indicate that equivalent amounts of heated air will be derived from all the convectors when used as body warmers. Identical values can be obtained when the fuel rate is regulated within 5 percent by continuous monitoring or by an automatic pressure control regulator.

5. Toxicity

Carbon monoxide concentrations at low-temperature operational conditions were undetectable. The wind velocity assured adequate dilution of the concentrations.

6. Safety Hazards

A thermocouple wire was discovered, during one of the tests, to have accidentally covered the secondary air holes of one of the burners. This was found to be the cause of a burner flameout and was detected by the temperature recorder. The burner was promptly shut off before propane fuel could accumulate. The chamber was exhausted immediately.

Although no serious hazard resulted from this event, extreme care was observed thereafter in keeping the burner secondary air ports clear of restrictions.

IV. Conclusions

A. Ignition

All prototype combustor-regulating valves must be prewarmed at low-temperature conditions and the burner tube shielded to assure ignition of the fuel.

B. Fuel Consumption

All three prototype convectors may be operated simultaneously without interruption at equivalent fuel rates continuously for periods up to 20 hours using a standard capacity propane fuel cylinder.

C. Fuel Regulation and Convector Effectiveness

Fuel rate and thermal capacitance regulation can be obtained within 5 percent.

D. Safety

The prototype convectors may be safely applied as body warmers for use with human test subjects, provided certain safety precautions are incorporated in the experimental design and closely monitored by test personnel.

V. Recommendations

It is recommended that:

1. the prototype convectors be used with human test subjects to complete the second phase investigation of this study.

2. the operational test point for all prototype convectors be fixed at a fuel rate of 2×10^{-2} pounds per hour $\pm$ 5 percent regulation.

3. in addition to the precautions on safety cited[3], the following specific limitations be incorporated in the experimental design of the application phase:

(a) The exposure of human test subjects shall not exceed four hours.

(b) The combustor-regulating valve assemblies shall not be cold-soaked, and shall be maintained at room temperature just prior to ignition of the burner.

(c) The inlet to the convector heat exchanger and the combustor-regulating valve assembly shall be kept clear of any restrictions, including thermocouple wires and clothing.

(d) A chromel-alumel thermocouple shall be placed in the convector at the baffle and connected to an audible alarm to signal flame failure.

VI. Acknowledgements

The author is indebted to the many technical support activities at the Natick Laboratories that facilitated the accomplishment of this investigation. In particular the assistance provided by Mr. Richard Giuggio, Electronic Technician, and Mr. James Lindsey, Engineering Technician, is especially noteworthy.

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APPENDIX I

Open-Flame-Type Convector

A General Description

Introduction

The open-flame-type convector is a hand-assembled, experimental prototype. This prototype convector is unique because it is designed to heat the space between the body and the outer apparel of the wearer.

The convector is small enough to be worn comfortably underneath the standard Army field jacket as shown in Figure 1. The envelope dimensions are 2-3/4-inches wide, 11-inches high, and 7-inches deep. It is also light enough to be worn for long periods of time without discomfort to the wearer. The assembled convector, including fuel for 18 hours of operation, weighs 2 pounds.

Basic Principles of Operation

Operation of the open-flame-type convector is dependent on the energy available from various combinations of hydrocarbons known as liquefied petroleum gases, or LPG. In the experimental prototype, propane is used as the fuel because its vapor pressure is sufficient to assure boiling or rapid vaporization at expected operational tamperatures as low as -40°F.

Propane, like other LPG's, is unique among fuels because it can be stored and transported as a liquid, and easily converted to a gas without external energy at temperatures down to -45°F. Under relatively low pressures and at normal temperatures, propane can be contained in its liquid phase. When released through a small orifice to the atmosphere at relatively low temperatures, propane vaporizes rapidly to a useful gaseous state for combustion. The change of state, resulting from the expansion of the propane, is accompanied by a high gas velocity sufficient to aspirate atmospheric air. Ignition of this high velocity air-fuel mixture produces an equally high-velocity flame front, which is stabilized by adjustment of primary and secondary air flow in a combustor tube.

When the high-velocity flame is directed at a metal target or baffle, inside a vertically oriented metal tube, a natural draft heat exchanger results. Heat is transferred by conduction from the baffle to the tube surface. In addition, the flame heats the column of air in the tube, setting in motion a forced-convection heat transfer process.

When the convector is placed in use as a warmer, the exchanger surface, in contact with the human body, is insulated to reduce the

Figure 1. Convector Worn Under Army Field Jacket

conducted heat transfer rate, and to increase the heat transfer by radiation and convection.

Description of Major Assemblies

Since the convector is a hand-assembled, experimental prototype, this section is limited to a general description of the major assemblies.

Figure 2 shows a front view of the convector in its principal operating position. Major assemblies are labeled and identified by a simplified nomenclature: the insulator, exchanger, combustor-regulator, and tank.

The insulator consists of a woolen cloth sleeve lined with asbestos sheet and shaped to fit snugly around the exchanger. The top and bottom seams are reinforced by a wire bound welt. An adjustable shoulder strap is attached to the top seam. The insulator is anchored to the exchanger at the bottom welt by a straight, stainless steel pin. The pin is provided with an eye at one end, to which a helical spring is permanently linked for use in securing the tank in place.

The exchanger consists of an 8-inch length of duct, cut from a rectangular section of standard, industrial-type aluminum conductor pipe. The top and bottom openings are capped by perforated plates. A 3/8-inch diameter hole is punched in the exchanger housing for insertion of the combustor tube. Inside the exchanger, above the combustor tube opening, a thin, stainless steel plate is flanged and riveted into position as a flame target.

The combustor-regulator is comprised of two major subassemblies: a standard, commercial, brass, tubular-type burner, and a pressure regulator. The burner is force-fitted to a hole drilled in the regulator housing and sealed in position with a permanent-type metal adhesive. The regulator is a standard diaphragm-type of valve, modified for manual control of the diaphragm position, and calibrated for very low propane flow rates.

The tank assembly is a standard, ICC-approved cylinder. It is filled with propane, and marketed as a commercial product.

Application and Use

The developer of the prototype claims that the unit "will keep the entire body warm, even the feet, while sitting or standing, at extreme temperatures. Not only is it a useful item for outdoorsmen, but for sports fans, outdoor workers, and people employed indoors in cold temperatures. Extremely light, it weighs only 2 pounds with a full fuel supply, and will provide comfortable heat when properly used. It eliminates the need for bulky or elaborate clothing. Its slim, streamlined designed does not interfere with body motion."

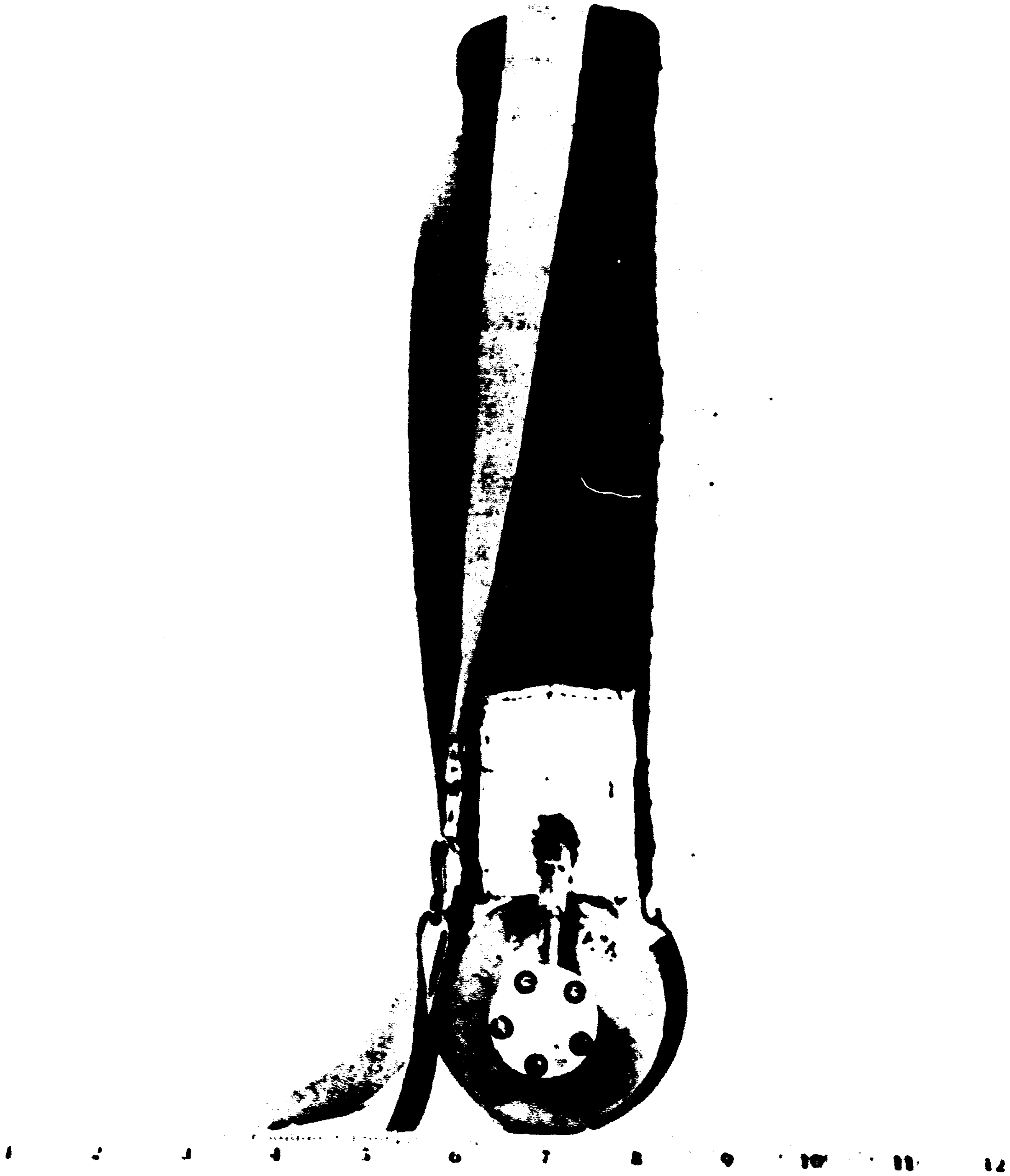

Figure 2. Convector in its Principal Operating Position
(Front View)

APPENDIX II

Experimental Design

Condition Cycle

Condition Number 1 - Standard

Condition Number 2 - Low temperature

Condition Number 3 - Low temperature, minimum level of operation

Fuel Throttling Index Sequence

	Condition		
Test Run Number	I	II	III
1	Low	High	Test Point
2	High	Medium	Test Point
3	Medium	Low	Test Point

APPENDIX III

Mean Performance Data - Convector Thermal Capacitance

	Exp No.	(1) Mean Heat Rate Q (Btu/Hr)	(2) Mean Inlet Temp T_1 (^oF)	(3) Mean Outlet Temp T_2 (^oF)	(4) Mean Temp Diff ΔT (^oF)	(5) Mean Thermal Capacitance wCp (Btuh/^oF)
Convector No. 1	1	358	57	215	158	
	2	373	56	219	163	
	3	376	59	235	176	
	4	357	61	226	165	
Avg of Means		366	58	224	166	2.20
Convector No. 2	1	350	75	238	160	
	2	389	66	227	161	
	3	389	73	243	170	
	4	393	67	219	152	
Avg of Means		380	70	231	161	2.36
Convector No. 3	1	351	72	228	156	
	2	365	72	239	167	
	3	353	69	248	179	
	4	353	70	252	182	
Avg of Means		356	71	242	171	2.08

SAMPLE CALCULATION:

Mean Thermal Capacitance = (Mass Flow of Air) (Specific Heat) = wCp

From Mass Heat Transfer Equation:
Mass Heat Transfer Rate = (Thermal Capacitance) (Temp Diff)
or $Q = wCp\ (T_2 - T_1) = wCp\Delta T$

Then: $wCp = Q/\Delta T = \frac{366}{166} = 2.20$ Btuh/^oF

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY U. S. Army Natick Laboratories Natick, Mass.

13. ABSTRACT

This report discusses the results of the first phase of an investigation to evaluate the performance of an open-flame convector which was initiated at the request of the Army Research Office, Department of the Army, and conducted at the Mechanical Engineering and Climatic Research Laboratories, U. S. Army Natick Laboratories. The convector investigated was an experimental prototype designed as a body warmer to heat the space between the wearer's body and his outer apparel.

Three prototypes were investigated under a series of conditions including standard, low-temperature, and operational. Under these conditions, data on ignition, fuel regulation, fuel consumption, convector thermal capacitance, and safety were obtained.

Results of the investigation showed that operation of the prototype convectors can be regulated for consistent operation within 9 percent. If the fuel rate is monitored and controlled, the convector thermal capacitance may be regulated within 5 percent to assure the constancy of this variable when applied to human test subjects.

Although there is a potential hazard of fire, heat injury and toxicity from use of the open-flame convector as a body warmer, its performance within safety threshold limits is obtainable. **(cont'd)**

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13. ABSTRACT (cont'd)

The fire and heat injury hazards are minimized when the fuel regulating valve is prewarmed at low temperatures and the burner is ignited in a shielded enclosure.

Carbon monoxide concentration was reduced to acceptance threshold limits, less than 0.01 percent, when the convectors were operated at low-temperature operational conditions.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Evaluation	8					
Heat distributing units	9		9			
Control	4		4			
Body temperature	4		4			
Ignition			8			
Fuel consumption			8			
Effectiveness			8			
Safety			8			

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